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EXPERIMENT AND EXPERIENCE IN CROP ROTATIONS

By John M. MUNRO

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EXPERIMENT AND EXPERIENCE IN CROP ROTATIONS

by

John M. Munro

Cotton Research Station, Uganda
Empire Cotton Growing Corporation

1. The ideal crop rotation is one which maintains or increases fertility while producing an economic return in crop or animal products. In primitive agriculture, this is usually achieved by shifting cultivation, where an area of land is cleared from bush or forest and cropped until the return becomes uneconomic; this area is then abandoned and a fresh area is cleared and cropped. Shifting cultivation in the savanna regions of Africa usually allows two to four years' cropping, followed by a recovery period lasting at least six years during which regeneration of indigenous species occurs; in humid tropical forest zones a much longer period of regeneration may be required (1).

2. With a low population density and plenty of land available, this system is adequate. All over the world, however, populations are increasing, and the problem in developing countries is how to feed this increased population while maintaining soil fertility. What has generally happened is that shifting cultivation has been carried on, but the recovery period has been more and more curtailed; fertility has fallen, more land is required to produce the same output, and the period of regeneration is shortened still further.

3. In Uganda, largely as a result of Martin's work (2) on the improvement of soil structure under grass, what is known as the 3:3 rotation has been advocated in the tall grass areas since 1934; in this rotation three years of arable cropping is followed by a three year recovery period under grass. Two years of arable cropping instead of three was recommended in the short grass areas. Many territories in Africa - Tanganyika, Kenya, Nigeria, the Rhodesias and Nyasaland - have based their cropping recommendations on this 3:3 rotation (3), although the effect of grass on the soil structure has been shown to be more transient than was thought at first (4).

4. One of the most difficult problems facing the agricultural scientist is the assessment of the value of a rotation in maintaining fertility, and the comparison of different rotations from this point of view. The choice of crops and of crop sequence is relatively a simple matter.

5. The choice of crops to be grown is based in the first place on what crops have been grown in the past, when trial and error decided the crops which were suited to the area and which found a ready market. This is developed by the selection and testing of improved indigonous varieties, and the introduction of varieties from other parts of the world. At the same time the development of communications widens the possible market, and new crops which have little or no local value, but can compete on the export market, are introduced and tested. As local industry develops, these crops may find a new market in the country where they are being grown. In the more highly developed countries, retail distribution is highly organized, and it is no longer necessary for the farmer to grow his own food; this type of development should be borne in mind in countries where subsistance farming with some production of cash crops is still the rule.

6. Having decided on what crops to grow, the sequence depends on the climate, length of growing season, and any interaction which may occur between crops. The first two are important in the equatorial belt where there are two rainy seasons a year, and where irrigation gives a wide choice of growing season. In both cases, peak water requirement should coincide with peak rainfall, and harvest with a relatively dry period. Timing is of great importance where two crops a year are taken, and the crop sequence must be arranged so that one crop is off the ground in time to plant the next crop at the optimum date. With one rainy season and one crop a year there is plenty of time during the dry season to prepare for the next crop. Rotations must be tried out on a farm scale before they can be recommended for general use, to ensure that no practical difficulties exist.

7. Some crops do better than others immediately following the regenerative period: cotton is recommended as an opening crop in Uganda (5), and groundnuts or tobacco in Nyasaland (6). Two year crop sequence trials have proved useful in Nigeria (7) and Nyasaland (6); in the latter, maize yields are found to be highest following a groundnut crop.

8. Intercropping - the planting of more than one crop on the same land in the same season - has for long been practised in Africa and elsewhere, and may be regarded as an alternative to the rotation of arable crops in pure stand. It is often difficult to compare such systems, which differ in the proportions of two different products, but recent work in Tanganyika (8) and Nyasaland (9) has shown that intercropping may result in higher total production per acre. Little or nothing is known of its effect on soil fertility.

9. As agriculture develops, increasing use will have to be made of cattle manure and artificial fertilizers to maintain and increase fertility. Where cattle are kept, traditional methods include not only the grazing of crop residues but also grazing of uncultivated rough pastures; the cattle are herded in a kraal or boma during the night. Cattle manure is therefore derived from outside as well as inside the rotation, but with more intensive cultivation the scope for free range gets less, and the ultimate aim must be the maintenance of fertility in a closed system as far as animal manure is concerned, but with increasing use of artificial fertilizers.

10. In a closed 3:3 rotation an output of half a ton per acre per annum of cattle manure is unlikely to be exceeded (10), which allows an average application of one ton per acre per annum to the cropping phase. Experiments at Serere in Uganda (11) (18) show that in a grass-arable rotation 2½ tons per acre every five years seems just sufficient to maintain existing fertility; 10 tons per acre every three years appears necessary to maintain continuous cropping. Continuous cropping in Tanganyika (12) with 6 to 7 tons per acre of cattle manure every fifth year gave yields equal to those following a five-year period of grass; double super phosphate at 200 lb. per acre gave similar results.

11. In Africa (13) as in England (14), it seems that the main value of cattle manure derives from the plant nutrients it contains, but the organic matter may play a part in delaying their release and in preventing the fixation of phosphates in certain soils (15).

12. There are many problems connected with the use of restorative crops in a rotation which have scarcely been touched so far. Probably the main stumbling block to the general adoption of a 3:3 or similar rotation is the question of an economic return from the land during the recovery period. In temperate climates, grass/legume mixtures are remunerative as a source of meat and milk; only now is this development starting in tropical and subtropical Africa. Milk production is remunerative when European breeds of cattle are maintained, but this entails a revolution in cattle management, with protection against tick-borne diseases, improved pastures, fencing and often conservation of fodder for the dry season. Beef production also requires a complete break with the tradition that cattle are an indication of wealth based on numbers alone, and a change to the concepts of quality beef and gain in live weight per acre per annum.

13. An alternative to beef and milk, especially where tsetse fly prevents the keeping of cattle, is the use of restorative crops producing a marketable product other than grass. Cassava weeded in the first season only has been shown to be as effective as grass in Tanganyika (12); in Nyasaland and Nigeria (3) pigeon pea (Cajanus indicus) is a possible alternative, while in Uganda (16) sugar cane in a 4:4 rotation is being used.

14. Much work remains to be done on the efficiency of different species of grasses and other crops in restoring fertility, alone and in combination with manuring. On the other hand there is some confusion as to what should be classified as "exhausting" crops; a distinction must be made between the direct effect of the crop and the effect of the cultivation methods. Cassava growing in Malaya is controlled by legislation, because it has rendered many acres of land useless for cultivation, in contrast to the restorative effect mentioned above in a rotation in Tanganyika.

15. Another difficult problem is the effect of the grazing animal on the restorative effect of a grass ley. Does grazing reduce or enhance this effect, and is there a difference in the effect of day time grazing only and the grazing of fenced paddocks day and night? Is maximum fodder production compatable with the maximum restorative effect?

16. The difficulty of assessing the value of a rotation in maintaining fertility lies chiefly in the length of time that is required. The most obvious measure of fertility is yield, but the effects of changes in fertility are usually small compared to variations in yield from season to season in tropical and subtropical regions. Yields from unreplicated plots are of little value unless they extend over very long sequences, although it may be possible to improve their value by some correction for climatic variation and position in the sequence of cropping.

17. Rotation experiments are exceedingly difficult to plan satisfactorily, and the results may only be relevant to a restricted area. In the first plance the number of possible permutations is usually very great, and only a few can be accommodated in an experiment of reasonable size. Secondly, to measure seasonal variations, all phases of the rotation should be represented each season; if six-year rotations are being tested, this multiplies the number of treatments by six. Thirdly, to accommodate the large number of treatments, replication may be restricted and statistically valid results may only be available after twenty years or more (17) (18). Fourthly, by the time that results become available the rotations tested may have been superseded as a result of information from other sources. Fifthly, the varieties used when the experiment started will almost certainly have been replaced by improved varieties.

18. The size and complexity of rotation experiments is such that few comprehensive trials have in fact been laid down and maintained. The Serere experiment in Uganda (11) was started in 1936, but the results of the first four completed cycles have not yet been fully analysed. At the Gezira Research Station in the Sudan a three-course rotation experiment was started in 1925, and the Combined Rotations experiment in 1931 (17).

19. To find the answers to the many problems of maintaining fertility by the conventional methods of rotation trials will involve an immense

programme of experiments and many years of work. A better knowledge of the principles involved would produce results in less time and of much wider application. These principles may be roughly divided into three - chemical, physical and climatic - although these will inevitably overlap and interact with each other.

20. In the past the chemical approach has been largely static: soil surveys have outlined the main edaphic and ecological areas, and in these the major nutrients have been measured on the sites of experiments, and the response to known applications of fertilizers have been measured by crop yields. The estimation of "available" nutrients necessitates arbitrary methods of extraction, and correlations between soil analysis and crop reaction to fertilizers has often been disappointing; a method which gives good results in one area is frequently unsatisfactory in another.

21. More attention has recently been given to the more accurate study of the movement of nutrients in the soil profile and in the plant material throughout the cropping and recovery periods of a rotation (1); leaching and the release of nutrients by weathering are also included. At the same time the movement and uptake of added fertilizers is being studied in the soil and in the crop (19).

22. The physical approach has already been touched on with reference to the effect on soil structure of grass roots (para.3). We need to know more about the influence of soil structure and texture on water penetration and water holding capacity, on soil aeration and drainage, and on the absorption and release of nutrients and their uptake by the plant. Mechanical cultivation can have a much more drastic effect on structure than the hand hoe which it is replacing as agriculture develops. Does organic matter have any appreciable effect on the physical properties of soil in the tropics?

23. Rainfall intensity affects the surface structure of the soil, and the translocation of nutrients depends on soil moisture; the climatic approach therefore is complementary to both the physical and chemical aspects. The water balance is dependent not only on the rainfall and water penetration, but also on the rate of evapotranspiration, involving solar radiation and energy balance. The hydrological balance depends largely on land use (20), and may have important effects on the availability and uptake of nutrients. Water and temperature affect the rate of weathering of soil minerals, and hence the chemical and physical changes going on.

24. A combined approach along these lines to the basic factors determining soil fertility should give us a much better understanding of the processes by which fertility is built up and maintained. It will help to interpret what is happening in rotation trials, and to extend their applicability beyond the site where they are carried out. It should also provide a link between long-term rotation trials and those of shorter duration which are more easily

carried out; and suggest new methods of maintaining and increasing fertility under more intensive cropping in the developing countries where this is of fundamental importance.

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